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# A planetary health innovation for disease, food and water challenges in Africa

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Many communities in low- and middle-income countries globally lack sustainable, cost-effective and mutually beneficial solutions for infectious disease, food, water and poverty challenges, despite their inherent interdependence[1–7]. Here we provide support for the hypothesis that agricultural development and fertilizer use in West Africa increase the burden of the parasitic disease schistosomiasis by fuelling the growth of submerged aquatic vegetation that chokes out water access points and serves as habitat for freshwater snails that transmit *Schistosoma* parasites to more than 200 million people globally[8–10]. In a cluster randomized controlled trial (ClinicalTrials.gov: NCT03187366) in which we removed invasive submerged vegetation from water points at 8 of 16 villages (that is, clusters), control sites had 1.46 times higher intestinal *Schistosoma* infection rates in schoolchildren and lower open water access than removal sites. Vegetation removal did not have any detectable long-term adverse effects on local water quality or freshwater biodiversity. In feeding trials, the removed vegetation was as effective as traditional livestock feed but 41 to 179 times cheaper and converting the vegetation to compost provided private crop production and total (public health plus crop production benefits) benefit-to-cost ratios as high as 4.0 and 8.8, respectively. Thus, the approach yielded an economic incentive—with important public health co-benefits—to maintain cleared waterways and return nutrients captured in aquatic plants back to agriculture with promise of breaking poverty–disease traps. To facilitate targeting and scaling of the intervention, we lay the foundation for using remote sensing technology to detect snail habitats. By offering a rare, profitable, win–win approach to addressing food and water access, poverty alleviation, infectious disease control and environmental sustainability, we hope to inspire the interdisciplinary search for planetary health solutions[11] to the many and formidable, co-dependent global grand challenges of the twenty-first century.

Infectious diseases, malnutrition and insufficient access to clean water burden poor communities worldwide. For example, around 264 million people are undernourished in Africa[12], people in Sub-Saharan Africa lose 40 billion hours per year collecting water[13], and 75% of deaths in low-income countries can be attributed to infectious diseases[5]. Disease, food and water challenges intersect in many ways, such as through widespread poverty–disease traps, whereby disease exacerbates malnutrition, stunts physical and cognitive development and reduces educational attainment, labour supply and incomes, all of which impede economic growth that can improve sanitation and access to energy, water, education and healthcare[1–4]. Despite their interdependence, disease, food and water challenges are typically addressed independently by governmental and non-governmental organizations, practitioners and researchers. Consequently, few convincing examples exist of sustainable, win–win planetary health (a transdisciplinary field that searches for sustainably beneficial actions for natural systems and human health[11]) interventions with real promise of breaking poverty–disease traps[3,4]. Even more rarely are the economic costs and benefits of win–win planetary health interventions quantified to demonstrate their cost-effectiveness and thus potential for widespread adoption[14].

An example of a neglected tropical disease with clear links to water and food production is human schistosomiasis[5–7], the world's second most common parasitic human disease after malaria with more than 800 million people at risk of infection[8–10]. Schistosomiasis is caused by snail-transmitted flatworms (*Schistosoma* species) that penetrate human skin; it reinforces poverty, adversely affects the health of children and adults, and defies control efforts, because even when infections are treated with drugs, people can quickly get re-infected when

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they return to snail-infested waterbodies[8–10]. In Senegal, the site of our experiment, *Schistosoma* prevalence in children often rebounds to 70–90% within a year after drug treatment, and more than 99% of host snails are captured in the freshwater plant *Ceratophyllum demersum*[15,16]. This plant has a mutualistic relationship with snails[17], is found throughout Africa, Southeast Asia and Latin America, where schistosomiasis is endemic, and along with other invasive aquatic plants, chokes out waterways impeding access to open water needed for washing clothes, irrigation and cooking[18]. Additionally, *C. demersum* is well documented to proliferate in the presence of fertilizer runoff[19,20].

We hypothesized that agricultural development in West Africa and the associated fertilizer use has led to increases in *Schistosoma* infections by increasing submerged aquatic vegetation and attached algae that are the habitat and food for snails, respectively (Fig. 1a,b; see Supplementary Table 1 for evidence to support this pathway). Based on this hypothesis, we predicted that we could decrease human *Schistosoma* prevalence and increase open water access by removing this vegetation from water access points. We also predicted that we could increase food production by returning the nutrients captured in this vegetation back to agriculture. This could help to reduce nitrogen and phosphorus pollution by partly closing the nutrient loop[21], while simultaneously providing an economic incentive to maintain cleared waterways. This would provide a mutually beneficial planetary health innovation for sustainability, disease reduction, water access, agricultural development and poverty alleviation that could facilitate adoption.

## Agricultural land use study

To test for associations among agriculture and schistosomiasis, we conducted collaborative research with 23 communities in the St Louis-Richard Toll region of Senegal (Supplementary Figs. 1 and 2). This region experienced a substantial increase in fertilizer use (many crops currently have more than 90% of surface area receiving fertilizer; Supplementary Table 5) after the construction of the Diama Dam, which was built to create a reservoir to facilitate irrigated agriculture[8] (Extended Data Fig. 1 shows the increase in greenery after dam opening). In each of these 23 communities, we quantified the amount of agricultural fields, fertilizer and other agrochemical applications within a 0.5-km radius from the centre of each village (Supplementary Tables 2–5); submerged aquatic vegetation in water access points (Supplementary Fig. 3); snails that transmit schistosome worms that infect humans (Supplementary Table 6); and human *Schistosoma* infections in approximately 1,700 schoolchildren (that is, using a combination of cross-sectional surveys and cohort studies; Methods and Supplementary Tables 7 and 8). Regression analyses (Supplementary Tables 9–14) revealed that each 0.1 km$^2$ of agricultural cover around a site was associated with a 1.37 odds increase of *Schistosoma* cases (combined *Schistosoma mansoni* and *Schistosoma haematobium* infections) in schoolchildren per community (95% confidence interval: 1.27–1.47, $P < 0.001$, Fig. 1c), and this pattern was robust to different methods of quantifying agriculture and controlling for freshwater habitat around sites and area of water access points (Supplementary Information, appendix 1). The best-fitting path model provided support for our proposed indirect pathway (Fig. 1a and Supplementary Tables 15–19). Total area of crops was linked positively with fertilizer use (Fig. 1d), which was positively associated with aquatic vegetation at water access points (Fig. 1e). Submerged aquatic vegetation was itself positively correlated with snail abundance (Fig. 1b), which in turn was positively associated with the prevalence of *Schistosoma* (both *S. mansoni* and *S. haematobium*) infections in schoolchildren (Fig. 1b and Supplementary Tables 18 and 19). The pathway from agriculture directly to prevalence was also significantly positive (Fig. 1b and Supplementary Tables 18 and 19), indicating that agriculture is somehow associated with schistosomiasis beyond this identified indirect pathway.

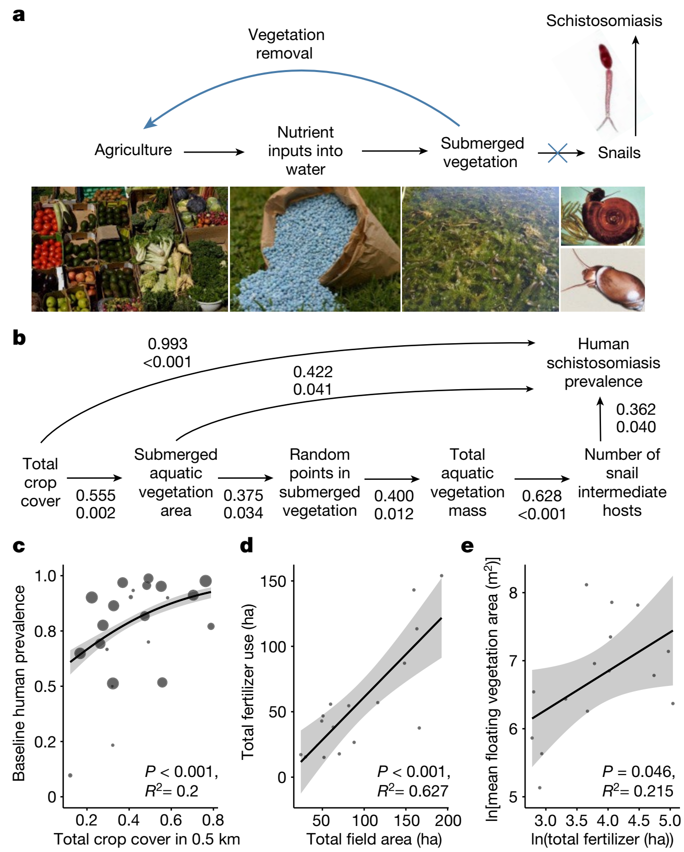


**Fig. 1 | Hypothesized and observed associations between agriculture and human schistosomiasis in Senegal. a**, Proposed pathway by which agriculture affects schistosomiasis and the proposal to disrupt human schistosomiasis by returning nutrients captured in aquatic vegetation back to agriculture. **b**, Best-fitting-path model for the associations between agriculture and prevalence of schistosomiasis infection in schoolchildren ($n$ = 23 independent villages, combined *S. mansoni* and *S. haematobium* infections; Methods). Positive effects are shown as black arrows and standardized effect sizes (top) and probability values (bottom) are provided under each path (calculated from a piecewise structural equation model; one-tailed tests are justified in Supplementary Table 1). Sampling effort (random points in submerged vegetation) increased proportionally to the surface area of submerged vegetation (Methods), and this surface area was associated positively with estimates of vegetation mass, which represent the primary three-dimensional habitat for snails. The final path model was a good fit to the data (test of directed separation: $C_{16} = 25.2$, $P = 0.067$; Supplementary Information, appendix 1). **c**,**d**, Regardless of whether we controlled for the human population size (Supplementary Tables 10–12), agriculture was positively associated with schistosomiasis prevalence in children (combined *S. mansoni* and *S. haematobium* infections; size of dots is proportional to the number of children tested) (**c**) and self-reported fertilizer use (**d**). **e**, Although fertilizer use was positively associated with the amount of aquatic vegetation ($R_s = 0.56$, $P = 0.034$), this pathway was not included in the path model because fertilizer use was available only for a subset of sites ($n$ = 16). **c**–**e**, Grey bands are 95% confidence bands and statistical tests were two-sided and conducted with generalized linear models. Images for agriculture and nutrient inputs into water in **a** are courtesy of FitNish Media on Unsplash and Anthony Trivet on Pexel, respectively.

## Aquatic vegetation removal trial

Given the positive association between agriculture and the prevalence of *Schistosoma* infections that seems to be mediated by aquatic vegetation, we predicted that we could disrupt this relationship and increase open water access by removing vegetation from water access points. To test this hypothesis, we implemented a three-year cluster

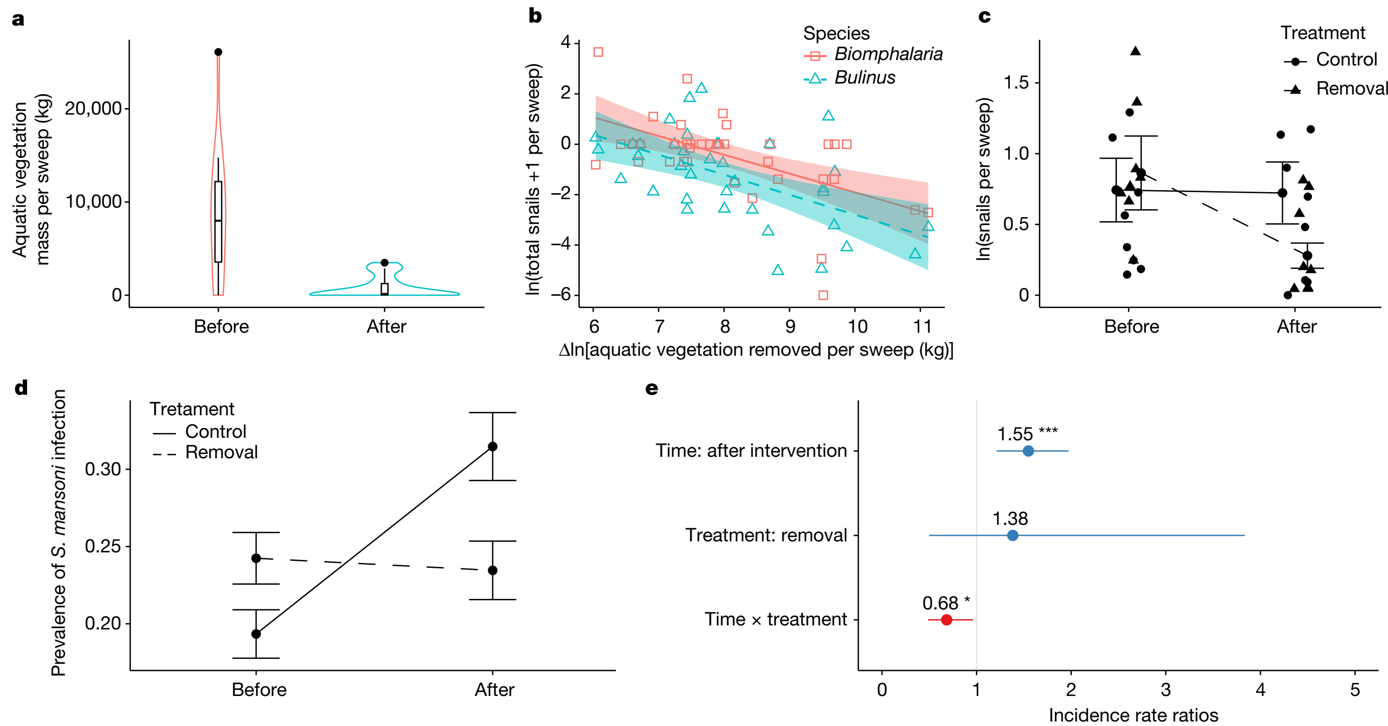


**Fig. 2 | The relationship between vegetation removal, snails and rate of infection. a**, Mean (midline) non-emergent vegetation mass per sweep removed during the first and subsequent quarterly vegetation removal events at 16 water access points located in 8 independent villages. In box plots, the box encompasses the first and third quartiles, whiskers represent the 95% confidence interval and points show outliers. **b**, Association (with 95% confidence bands) between aquatic vegetation removed at water access points and the change (Δ) in *Bulinus* spp. snails collected per sweep before and after the initial vegetation removal. **c**, Mean (±s.e.m.) number of snails per sweep sampled at the same locations before (data points are the 8 independent villages per treatment) and after the initial removal event. **d**, Marginal mean prevalence (±s.e.m.) of *S. mansoni* in schoolchildren before and after the implementation of the vegetation removal intervention (*n* = 8 independent villages per treatment). **e**, The exponentiated incidence rate ratio coefficients (and 95% confidence interval) for the effects of time (before or after intervention), treatment (vegetation removal or not), and the time-by-treatment interaction on the community-school mean rate of infection with *S. mansoni*. The significant coefficient for the time-by-treatment interaction indicates that the *S. mansoni* infection rate in the vegetation removal sites was 68% of that observed in the control sites; in other words, the controls sites had 1.46 times the infection rate of the removal sites.

randomized controlled trial in 16 communities (clusters) in Senegal (Supplementary Figs. 4–6; see CONSORT clinical trial checklist (Supplementary Table 20)), quantifying the effort to remove vegetation, abundance of snails, aquatic vegetation, open water and *Schistosoma* infections (prevalence and egg burden) in more than 1,400 schoolchildren before and after removal of vegetation in half of the communities (Supplementary Table 21). All infected schoolchildren received praziquantel annually to treat *Schistosoma* infections regardless of whether *Schistosoma* eggs were detected in their faeces or urine (Methods, Supplementary Table 22 and Supplementary Fig. 6). Given that praziquantel has an approximately 85% efficacy at clearing infections[22], we conservatively describe tracking infections rather than reinfection rates. Hence, our pre-registered primary outcome is a difference in the change in prevalence of human *Schistosoma* infection between the control and intervention arms, whereas a change in snail responses were the pre-registered secondary outcomes (Methods and Supplementary Table 20). Of note, control villages and those in which vegetation was removed (hereafter referred to as 'removal villages' or 'removal sites') had similar characteristics at baseline, although the removal villages had slightly larger field areas and corresponding fertilizer use (Extended Data Table 1).

We removed an estimated 433 metric tons (wet mass) of submerged aquatic vegetation during the study and removed significantly more vegetation on the first visit (mean: 14.21 metric tons) than during subsequent quarterly revisits (mean: 2.04 metric tons, $P < 0.001$; Fig. 2a, Extended Data Fig. 2 and Supplementary Tables 23 and 24). Consequently, the labour costs of removing vegetation dropped significantly relative to the first removal ($P < 0.001$) and remained relatively constant thereafter (Extended Data Fig. 2). Additionally, if villagers wanted more aquatic vegetation, there was no shortage because they could easily move outside their water access points to collect more vegetation on the river or lake. We sampled 7,833 snails and vegetation removal was associated with an eightfold reduction in the number of snails in the following year (time × treatment: $P < 0.001$; Fig. 2c and Supplementary Tables 25 and 26; see Extended Data Table 2 and Supplementary Tables 27 and 28 for details on each snail species). The more vegetation we removed, the more *Biomphalaria* and *Bulinus* snail abundance declined (bivariate correlation rho = −0.46, $P < 0.001$; Fig. 2b) and the greater the area of open water access was available to community members (time × treatment: $P = 0.026$). We encourage future studies to quantify the saving in water collection time as a result of this increased accessible open water area.

The baseline average intestinal *Schistosoma* egg count among infected schoolchildren was 161 eggs per gram of stool (s.d. = 383 eggs, mean = 33 eggs (including both infected and non-infected individuals), Supplementary Table 29), which is characterized as a moderate intensity by the World Health Organization[23] (WHO). After the intervention, the percentage of schoolchildren infected with *S. mansoni* in vegetation removal sites was 23.5% (confidence interval: 19.8–27.2%) whereas in control sites, 31.5% of schoolchildren were infected (confidence interval: 27.2–35.8%) (Supplementary Table 29). A conservative statistical model revealed that the infection rate of *S. mansoni* in schoolchildren in the vegetation removal sites was 68% of the infection rate observed in the control sites ($P = 0.03$; Fig. 2d and Supplementary Tables 29–32).

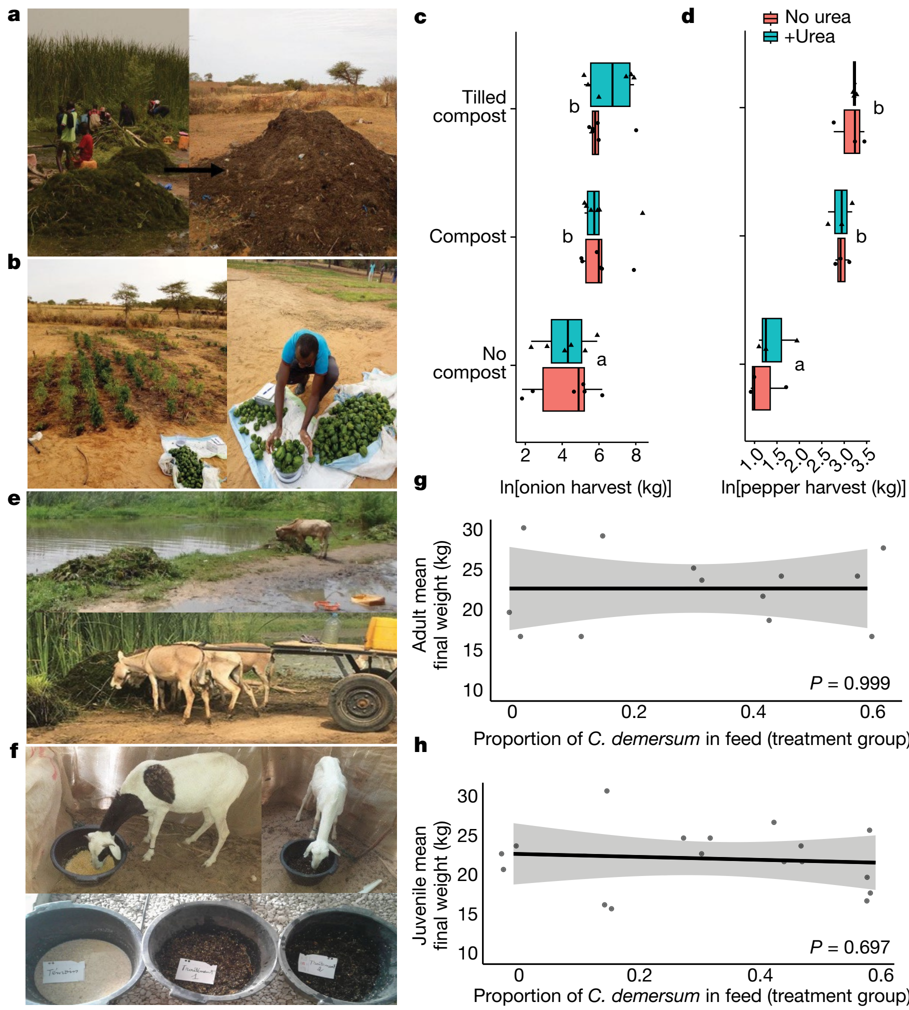


**Fig. 3 | Use of nuisance aquatic vegetation as compost and livestock feed to increase food production and profits. a**, Photographs of aquatic vegetation and compost piles. **b**, Photographs of pepper plots receiving compost, fertilizer and tilling treatments and the farmer collecting data for the project. **c**,**d**, The compost increased onion (**c**) and pepper (**d**) production per 11 m$^2$ subplot independent of the cross-randomized tilling or fertilizer treatments. In box plots, points show independent replicates, midlines represent medians, boxes delineate first and third quartiles and whiskers extend to 1.5 times the interquartile range. Compost treatments with different letters are significantly different from each other on the basis of two-tailed tests with Bonferroni adjustments to an alpha of 0.05. **e**, Photographs of cattle and donkey readily consuming the removed aquatic vegetation, which is almost exclusively *C. demersum*. Goats refused to eat *C. demersum*. **f**, Sheep and feeds used in sheep trials. **g**,**h**, Final masses of adult (**g**) and juvenile (**h**) sheep were similar to controls when their normal diet was substituted isocalorically with up to 60% *C. demersum* (shown are regression lines, jittered points representing independent sheep replicates and 95% confidence bands). The age class of the sheep had no significant effect on sheep weight ($F_{1,28}$ = 0.14, $P$ = 0.71; two-sided test).

As predicted, the effect of vegetation removal was weaker for *S. haematobium* than for *S. mansoni*, but it did not cause harm (Supplementary Tables 33 and 34; discussed in Supplementary Information, appendix 3). Additionally, we found no evidence of changes in human–water contact following vegetation removal (Extended Data Tables 3 and 4 and Supplementary Tables 35–38), and note that any induced increase in human–water contact would be expected to attenuate estimated effects on infection rates.

In only three vegetation removal sites was the total difference between vegetation mass sampled after removal versus vegetation mass before removal more than 3 kg per sweep, because there was either little vegetation to remove, substantial regrowth between visits or vegetation blown in from deeper waters. Only at these three intervention sites did *S. mansoni* not decline, further corroborating the benefit of removing aquatic vegetation and suggesting that shorter removal intervals may be necessary when vegetation regrowth is particularly rapid or *Schistosoma* transmission is extremely high[24,25]. Our results are consistent with the results of smaller-scale studies on vegetation removal[24,26] that focused only on *Schistosoma*-harbouring snails and not human infections[27] or were confounded with molluscicide applications[24], and corroborate predictions from mathematical models that *Schistosoma* prevalence should decline more rapidly with vector control than with drug treatments alone[22,28]. Although the results of our cluster randomized controlled trial demonstrated that vegetation removal reduces *S. mansoni* infections and are consistent with models and other studies, replication of this work on more sites across an even larger spatial scale would be required before widespread implementation.

Of note, there were no adverse effects of removing this overgrowth of invasive vegetation[18] on water quality or chemistry (Extended Data Table 5). Given that these water access points are contiguous with the river or lake, the reduction in vegetation—which serves as habitat for freshwater biodiversity (such as snails)—was localized and temporary, indicating that the vegetation clearing probably has no long-term adverse effects on the aquatic ecosystem as a whole. We expect that the limited scale of the removal of invasive vegetation—that is, only at water access points—may obviate any ecosystem effects. Additionally, before the Diama Dam was constructed, agriculture, vegetation (Extended Data Fig. 1) and schistosomiasis prevalence were all lower[8].

Thus, removing this invasive vegetation probably shifts these systems towards an earlier, pre-disturbance state (Extended Data Fig. 1).

## A private good from a public health nuisance

Because aquatic plant overgrowth appears to be caused at least partially by runoff from agriculture, we hypothesized that we could profitably improve food production by returning the nutrients captured in the removed plants to agriculture, thus reducing nitrogen and phosphorus pollution by partly closing the nutrient loop[21] (Fig. 1). To test this hypothesis, we collaborated with local farmers and small-scale livestock owners to evaluate whether the removed aquatic vegetation could be cost-effectively converted to compost to increase crop yields (Fig. 3a–d and Supplementary Fig. 7) and/or used as livestock feed (Fig. 3e–g) (Methods). The compost was reasonably high in moisture, nitrogen and phosphorus (Extended Data Table 6), increased production of both onion and pepper (total mass) independently of whether the compost was tilled in the soil or applied with fertilizer (Fig. 3c,d and Supplementary Tables 39–41), and onion rot was significantly greater in plots with both fertilizer and compost than in those with compost alone, further supporting the use of compost as a substitute for fertilizer (Extended Data Fig. 3 and Supplementary Table 41, $P < 0.001$). Additionally, compost increased onion and pepper yields to a significantly greater degree than urea fertilizer (Fig. 3c,d), probably because it increased the water holding capacity of the soil. Depending on the compost treatment arm, crop, wage estimates and crop valuation, conservative private benefit-to-cost ratios ranged from 2.7 to 4.0 and were always significantly greater than 1, indicating that the conversion of removed vegetation to compost was highly profitable, and much more profitable than urea fertilizer (Supplementary Table 42; additional details on the economic analyses in Supplementary Information, appendix 2).

Sheep, donkeys and cattle, but not goats, readily consumed the removed aquatic vegetation, suggesting that it might be useful as livestock feed (Fig. 3e,f). Using 17 female juvenile sheep and 13 female adult sheep, we applied isocaloric substitution of the typical purchased feed (a mix of peanut straw and pellets for juveniles and cornmeal for adults) with the removed aquatic vegetation (*C. demersum*) and tracked the growth of the sheep (Supplementary Table 43). The vegetation was first dried and ground with a pestle in an effort to kill any helminth eggs or cysts (including *Fasciola* spp.) and then reconstituted with water (Methods). We found no significant effect of any feed substitution level up to the 60% maximum on sheep weight gain or growth in either age group (Fig. 3g,h and Supplementary Tables 44–45). The cost of aquatic vegetation per calorie is 0.10–0.20 XOF (US$0.0002–US$0.0004), whereas the cost per calorie of peanut straw and cornmeal are 13.39 – 17.86 XOF (US$0.02–US$0.03) and 8.29 XOF (US$0.01), respectively. Thus, when including labour costs, feeding sheep aquatic vegetation is 41 to 179 times less expensive than purchasing traditional feed for sheep (Supplementary Tables 46 and 47). Using the removed vegetation as compost had a higher private benefit-to-cost ratio than using it as livestock feed (Supplementary Tables 42 and 46–49), consistent with the observation that sheep graze freely, especially when forage is available, obviating the need to purchase feed. Including a highly conservative estimate for the public health benefit of reducing schistosomiasis (Methods and Supplementary Table 50) adds 15–22% to the gross private benefits of using the vegetation as compost, resulting in total benefit-to-cost ratios of 3.1–8.8 (Supplementary Table 48), and using vegetation as livestock feed sharply reduces costs (without loss of benefits) during those occasional periods when farmers supplement grazing with purchased feed. Although the benefit-to-cost ratios are already high, we expect them to increase with time as intervention costs decline and benefits rise (discussed in Supplementary Information, appendix 4). However, various factors will affect the extent of individuals receiving these private benefits (Supplementary Information, appendix 4).

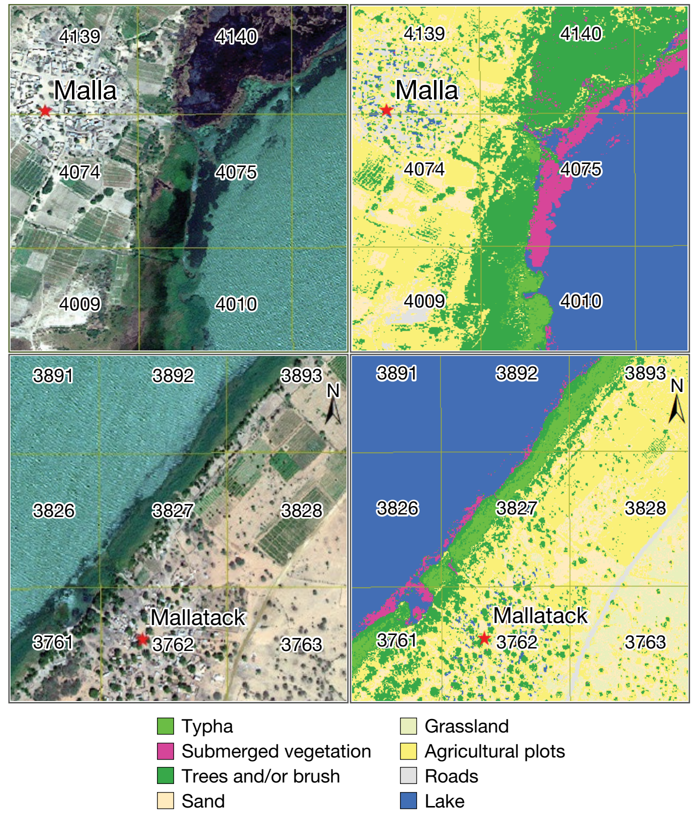


**Fig. 4 | Ability to discriminate among submerged vegetation, emergent vegetation (*Typha*) and open water on the basis of red, green and blue values only.** We utilized the image classification training tool in ArcMap (release 10) on 8-band raster data (including 2 near-infrared bands) from WorldView-2 imagery files obtained from the DigitalGlobe Foundation. Image classification training was based on the eight indicated categories and randomly selected pixels in each habitat. After training was complete, the resulting classification was applied over the larger water access area using maximum likelihood. Fuchsia indicates high densities of *C. demersum*, representing snail habitat.

We observed prosocial behaviour in the form of regular, voluntary community engagement in the vegetation removal process after we educated community members on the expected public health benefits of this intervention. Nonetheless, relying purely on voluntary labour to clear the vegetation will almost surely result in suboptimal vegetation clearing and higher prevalence of *Schistosoma* infections relative to the condition where they perceive and act on private benefits. By converting the public nuisance—aquatic vegetation—into a profitable agricultural input, we provide a private economic incentive to maintain cleared waterways, generating public health co-benefits along with higher private incomes. Although it remains to be tested, we expect that communicating these private benefits to community members will increase vegetation removal relative to communicating the public health benefits alone, which could help marginalized communities to escape poverty–disease traps[4]. Competition for private benefits of a public resource (aquatic vegetation) will probably require communities to manage access to the vegetation and thus prevent conflict, a potential adverse side effect of this innovation.

## Scaling plan

Given that our intervention offers a mutually beneficial innovation for several societal challenges (Figs. 2 and 3) and there was some level of interest in adopting the intervention, we began developing a scaling plan. We hypothesized that we could use satellite imagery to identify snail habitat and thus potential schistosomiasis hotspots, which would then facilitate targeting our intervention to where it is needed most. The application of a deep learning fully convolutional neural network (with 80% training and 20% validation sets; Methods and ref. 29), enabled us to reliably discriminate submerged vegetation from emergent vegetation, open water and land (segmentation accuracy for the submerged vegetation was 97.0% for the training set and 84.0% for the validation set[29]; Fig. 4). This suggests that there is considerable potential to use remote sensing to facilitate targeting and scaling of this intervention[16]. Scaling of this intervention could also be further assisted by investigations of (1) vegetation removal intervals, spatial scales[30], compliance and mechanization; (2) other economic uses of the vegetation; and (3) the efficacy of the intervention in other parts of the world.

## Conclusions

We provide support for the hypothesis that agricultural development in West Africa and associated fertilizer use are increasing the devastating human disease schistosomiasis by fostering the growth of aquatic plants that function as snail habitat. By removing this vegetation and returning the nutrients captured in it back to agriculture, we offer a profitable and environmentally responsible innovation for several of the most formidable, co-dependent global grand challenges of the 21st century—environmental sustainability, food and water access, poverty alleviation and infectious disease control. Our innovation aligns with the United Nations Sustainable Development Goals[31] and synergistically leverages principles of ecology and the social, environmental and agricultural sciences. An important lesson from this work is that many communities in low-income countries do not automatically identify and use seemingly simple, low-cost, effective local interventions, such as converting nuisance aquatic vegetation into a free resource. Although local knowledge is extensive and needs to be respected, there appear to be opportunities to use systems-level insights that may elude local communities to help them to improve their well-being. Consequently, we encourage educating communities in Western Africa about this innovation and optimal fertilizer use given their consequences for aquatic and disease ecology. Notably, identifying similar planetary health innovations must be a priority and will probably require capitalizing on interdisciplinary, systems-based approaches to beneficially modifying the built and natural world and designing incentives for community-led maintenance of innovations with both public and private benefits. We hope that this project offers a prototype planetary health innovation both for similar agricultural, health, water and sustainability challenges as well as for other co-dependent grand challenges[32].

## Online content

Any methods, additional references, Nature Portfolio reporting summaries, source data, extended data, supplementary information, acknowledgements, peer review information; details of author contributions and competing interests; and statements of data and code availability are available at https://doi.org/10.1038/s41586-023-06313-z.


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## Methods

### Study area and village selection

For the study testing for an association between agriculture land use and schistosomiasis, we selected 23 sites from a list of >700 sites as fully described by Wood et al.[16]. In brief, the study region was geographically limited to the administrative regions immediately touching the Senegal River, Lac de Guiers or connected irrigation canals between the Ocean and the Lac de Guiers, in northern Senegal (Supplementary Fig. 1). This geographic restriction included the districts (and respective communes) of St Louis (Fass Ngom, Gandon) Dagana (Bokhol, Dagana, Diama, Mbane, Richard Toll) and Louga (K. Momar Sarr, Nguer Malal, Syer) and reduced the eligible sites to 400. Remaining communities were visited on Google Earth (Google Earth 7.1.2.2041) and sites were selected that were not within protected areas, had access to permanent freshwater without large-scale drainage or vegetation clearing projects that could impact snail or plant distributions, a small human population (<2,215 persons), an active school with 30–130 enrolled children, ≤4 water points accessed by community members that were not on private land, and permission from the community leader for us to sample the water access points. After visits to 133 communities from January 2015 to January 2016, 16 communities met the inclusion criteria and were selected for the vegetation removal cluster randomized controlled trial (Supplementary Figs. 4 and 5). We relaxed the community population size criterion to <3,000 people to include seven additional sites for the correlational agricultural land use study (that is, seven sites were only sampled in 2017, whereas the other 16 were sampled repeatedly from 2016–2018). The primary source of water for the communities was the local (open) water access points, as only two communities had a functional water well, and only one of those had electricity.

### Agricultural land use study

Within the 23 sites selected for the correlational study exploring the relationship between agricultural land use and schistosomiasis, we created sampling polygons at each water access point that encompassed all open water and submerged and floating vegetation, extending laterally several metres into the dense emergent vegetation border (Supplementary Fig. 3). The outer limit of each sampling polygon was determined by water depths at which technicians could safely sample wearing chest waders. Technicians sampling snails or removing vegetation wore both chest waders and shoulder length gloves as personal protective equipment (PPE). During removal, PPE was worn by adult male community members who were paid an hourly rate to remove aquatic vegetation. To quantify vegetation within the polygon, we collected aerial photographs using an unmanned drone with a 12.4-megapixel camera and geo-referenced using QGIS 3.2 (https://qgis.org/en/site/) to estimate the area (in $m^2$) of submerged aquatic vegetation or snail habitat (Supplementary Fig. 3). We summed vegetation area (in $m^2$) per village because the human infection data are only available at the village level (see below). All of these procedures are also published in Wood et al.[16].

In addition to using QGIS to map the water access points, we used QGIS to quantify agricultural cover and freshwater habitat within a 0.5-, 1- and 2-km radius buffer from the centre of each village applying the Food and Agriculture Organization of the United Nations (FAO) produced LANDSAT ETM (remote) images of Senegal with a spatial resolution of 30 m (Supplementary Tables 2, 3). The FAO data were verified by an accuracy assessment using 10-m-resolution Google Earth imagery and ground truthing in Senegal[33].

Because FAO data did not include agrochemical application rates, we also conducted a household survey based on the children who were enrolled in the parasitological study. In the summer of 2016 in the 16 sites used in our cluster randomized controlled trials (Supplementary Table 3), we conducted surveys of the extended family households (that is, concessions) where the children lived ($n$ = 663 households). The number of households per village varied with the size of the village from 16 to >60 households. All data were self-reported by the head of the household. The household survey instrument included a module on self-reported agricultural practices (Supplementary Table 4). In this module, each household reported area of agricultural land under its control, the crops that were grown on each field and what type(s) of agrochemicals (for example, fertilizer and herbicide), if any, were used on those crops (Supplementary Table 5). Survey questions and response categories were developed initially in English before being translated to French. All survey questions were discussed in detail with members of the field team who were knowledgeable about agricultural practices in the area and what agrochemicals are commonly used. Survey questions were reviewed in French and the proper terms and ideas in Wolof, the dominant local language spoken in these communities, were discussed at length and agreed upon by all members of the field team. A team of eight Senegalese enumerators were trained to obtain verbal informed consent from survey participants, to pose survey questions in Wolof and record data in French. The survey instrument was pilot tested in one non-study community before being deployed in the 16 studied communities.

### Aquatic vegetation removal cluster randomized controlled trial

The 16 sites selected for the cluster randomized controlled trial (see CONSORT clinical trial checklist[34]; Supplementary Table 20) had a total of 32 water access points used by community members (1–4 per site), within which we created sampling polygons encompassing all open water and submerged and floating vegetation, as described above for the agricultural land use study. During each vegetation removal round, we removed submerged vegetation from all sampling polygons of the eight removal sites, with three sites starting in 2017 and eight sites in 2018 (for feasibility and logistical reasons; Supplementary Fig. 6). We removed vegetation quarterly for one year within a one- to two-week period for all sites (Extended Data Fig. 2 and Supplementary Fig. 6). We estimated the mass of vegetation removed by comparing the vegetation piles on the shoreline of water points (vegetation shaken to remove water) to standardized volumes of each plant species to convert field measured volume to a total estimated mass removed (in kg) (Extended Data Fig. 2 and Supplementary Tables 23 and 24). We also recorded the number of person hours required for each quarterly vegetation removal. Random cluster assignments were conducted by the Biomedical Research Center Espoir Pour La Santé (EPLS) with a random number generator within lake and river sites to ensure four villages per treatment in each of these location types. We also stratified the random treatment assignment to ensure there were no significant differences between treatments in numbers of water access points and community population sizes (Extended Data Table 1). The pre-registered primary outcome of the trial is a difference in the change in human *Schistosoma* prevalences between the control and intervention arms (ClinicalTrials.gov: NCT03187366 Record R01 TW010286). The pre-registered secondary outcomes are a difference in the change in snail densities, prevalences and number of infected snails between the control and intervention arms.

### Snail sampling protocols

To sample snails in the 16 sites used in our agricultural land use assessment and cluster randomized controlled trial, we created 15 random sampling points within each polygon described above, with points stratified across three potential snail habitats (open water, non-emergent vegetation, emergent vegetation) based on their proportional cover found by aerial photography and a visual estimation by technicians on the date of sampling. We exhaustively sampled each quadrat (76.2 cm length × 48.26 cm width × 48.26 cm height; area = 0.3677 $m^2$) placed at these points using a 2.5-mm mesh aquatic dipnet, all as described in Wood et al.[16]. We took sample contents to the shore where we shook all non-emergent vegetation to remove the snails, weighed the vegetation using a spring scale, and identified and counted *Bulinus truncatus* and

*Bulinus globosus* spp., and *Biomphalaria pfeifferi*, which are intermediate hosts to the human schistosomes *S. haematobium*, and *S. mansoni*, respectively. We sampled for snails annually during the dry season at the same GPS locations both before and after a vegetation removal at water access points of each community.

At the seven additional sites used in the agriculture land use assessment study, we used identical snail sampling methods except that we performed a 1-m sweep at each random sampling point using a 45 × 40-cm aquatic dipnet with a 2.5-mm mesh, instead of exhaustively sampling a quadrat with a 2.5-mm mesh net. Given this minor difference in the snail sampling methodology, we performed a separate study using the quadrat and sweep net methods side-by-side at 218 random points. We compared snail counts between the two sampling methods, by performing a negative binomial regression with village as a random intercept to account for re-sampling the same village. These analyses demonstrated that both methods captured similar numbers of snails ($\chi^2 = 0.76$, d.o.f. = 1, $P = 0.383$; Supplementary Fig. 8).

### Human sampling

A power analysis revealed that 75 individuals should be sufficient to accurately quantify infection rates. Additionally, a power analysis with a medium effect size indicated that 8 treated and 8 control communities in a before–after control–impact (BACI) design would be sufficient to detect effects of treatment. Hence, we selected 16 communities and targeted and average enrolment of about 75 schoolchildren where possible. Consequently, a total of 1,479 school-aged children were treated with praziquantel at the 16 communities in April 2016 in the cluster randomized controlled trial and 211 school-aged children were treated at the additional seven sites added for the agricultural land use study in 2017 (Supplementary Tables 7, 8, 29 and 30). Parasite identification was blind to treatment and performed by EPLS in Saint Louis, Senegal, using urine and faecal samples from these children to determine human infection by *S. haematobium* and *S. mansoni*, respectively. *S. haematobium* in children was quantified by urine filtration using standardized methods[35]. Two 10-ml samples were separately filtered and analysed by different observers. *S. mansoni* infections were determined by collecting stool samples and using the Kato–Katz assay[36]. Two Kato–Katz slides were run per stool sample. We chose not to use molecular techniques for *Schistosoma* quantification because these methods currently cannot reliably discriminate *S. mansoni* from *S. haematobium* in co-infections, which are common in this region. For the cluster randomized controlled trial, the same children were then tested and treated annually from 2017–2018 to quantify infection rates each winter season at the village level (Supplementary Fig. 2; only one child did not show up to school in the follow-up year during this time interval (Supplementary Fig. 4)). New children were recruited to the study as needed when children left the school, and thus we could not always track the same children throughout the study. Thus, we could examine baseline infection at all 23 sites in 2016, but infection post-treatment for control villages in 2017 and 2018 for only 16 sites.

To determine whether human–water contact was influenced by vegetation removal, we made one-hour observations of the number people visiting the water, and recorded individual-level variables including: age group, the level of water immersion, as parasite exposure risk rises with body surface area immersed, and the duration of the water contact. We twice assessed water contact at water access points at each of two control and manipulation sites for two time points both before and after vegetation removal, holding constant the time of day of visits to each site so as to control for diurnal variation (Extended Data Tables 3 and 4 and Supplementary Tables 33–36).

Subject enrolment, informed consent from the parents or guardians of child participants, human sampling and drug administration were all conducted by EPLS, approved by the National Committee of Ethics for Health Research from the Republic of Senegal (Comité National d'Ethique de la Recherche en Santé; CNERS, Dakar, Senegal; protocol no. SEN14/33), and conducted in accordance with the Declaration of Helsinki III and with the International Ethical Guidelines for Biomedical Research Involving Human Subjects as set forth by the WHO guidelines for good clinical practice[37]. Additionally, this study was also approved by the University of South Florida Internal Review Board (protocol no. MS7_Pro00017473) and the University of Notre Dame (18-10-4951), and is registered on ClinicalTrials.gov (NCT03187366 Record R01 TW010286). Consent was sought after randomization. Any infected children found during data collection were offered the anti-schistosome drug praziquantel (40 mg $kg^{-1}$) and all human data were anonymized prior to analysis to protect the identity of participants. A full description of participant demographics and numbers of children tested in each site is presented in Supplementary Tables 7, 8 and 29.

### Crop compost experiments

Following the first round of vegetation removal, we dried vegetation along the shoreline of two sites for several days and then placed it into an earthen pit (approximately 3.5 × 3.5 × 0.5 m) at each village, along with an aliquot of animal manure to seed the pile with bacteria that could initiate the decomposition. The pits were covered with a layer of soil in June 2017, but periodically uncovered to monitor its moisture and texture until June 2018, when we randomly sampled 10 locations within each compost pit and then mixed each pit to create a final 1-kg composite sample for lab analyses of its nutrient and moisture content (Extended Data Table 6).

In June 2018, we performed a 2-factor split-plot experiment wherein we divided a field into 6 equal rows or blocks, half of which were assigned the whole-plot (33 $m^2$) treatment of fertilizer addition (urea condition (U) with 8 g urea per plant and no urea (NU) condition), with each row divided equally into three randomly assigned split-plot (11 $m^2$) treatments (C, compost added to soil surface; TC, compost hand tilled into the soil; NC, no compost) (Supplementary Fig. 7). Farmers in the region predominantly use fertilizer rather than produce compost, which is why we included a fertilizer treatment (urea) rather than a compost treatment derived from a different source of organic material. We applied compost at approximately 7 kg $m^{-2}$ in C and TC plots and planted a local stock of 1,100 pepper seedlings spaced 0.5 m apart in each plot. We quantified the number of peppers and their mass (in kg) produced per plot when harvested from the field (every 10 days) until the end of the harvest period. This same experiment was then repeated in 2019 for onion production on a novel field using the same planting density and spacing as above. We used an Orient-F1 variant of *Allium cepa* (red onion) (LOT: 1257085) using seeds that were pre-treated with the fungicide metalaxyl-M. We planted Orient-F1 seeds on 6 February 2019, with community members applying equal amounts of water to all plots beginning on 18 April 2019. We then harvested all onions on 7 June 2019. In each trial, the farmer weighed and counted the peppers and onions from each plot and recorded any evidence of infections on the crops, such as onion rot.

### Livestock feed experiment

Sheep livestock are commonly raised by rural families due to their adaptation to the harsh Sahelian environment, their short production cycle, low upkeep costs, religious importance, and value for certain Muslim holidays, such as Tabaski. Farmers can generate income or benefits including milk, meat, offspring (lambs) and manure for fertilizer. Sheep can be grazed on natural pasture but may be housed in shelters, due to their value, and fed a variety of grain or forage (that is, cornmeal, peanut straw or pelletized composite feeds).

To determine whether aquatic vegetation removed from waterways provides a viable livestock feed supplement, we purchased a total of 30 female sheep in two groups of similar sized ewes and randomly assigned each to one of five treatments. Sheep were stratified by weight so that all treatment groups had a comparable initial mean weight at the start of the two phases of the experiment. An ANOVA revealed that the starting weights among the five treatment groups did not differ (phase 1: $F_{1,11} = 1.624$, $P = 0.229$, phase 2: $F_{1,15} = 0.47$, $P = 0.750$; Supplementary Table 43). The five treatments were 0, 15%, 30%, 45% and 60% replacement of their standard feed, cornmeal (adults) or peanut straw (juveniles), with *C. demersum* that was dried (2 weeks) to kill helminth eggs and cysts, ground with a pestle, reconstituted with water (1,000 g), and mixed to create a relatively homogenous mixture of cornmeal or peanut straw and *C. demersum*. The phase 1 trial involved adult ewes, whereas the phase 2 trial started with six-month old juvenile ewes. All sheep were maintained individually in enclosures so we could control what they ate and were fed daily at the caloric equivalent of 1,000 g of cornmeal. Weight was assessed weekly. A veterinarian technician was on staff to monitor animal welfare and weight gain or loss during the experiment. These procedures were approved through the University of Notre Dame Institutional Animal Care and Use Committee protocol number 7444.

### Remote sensing analyses

We received a grant from the DigitalGlobe Foundation that provided sub-metre, visible and near-infrared imagery of northern Senegal (taken by WorldView-2 and WorldView-3 commercial satellites) that we coupled with fine scale maps of open water, *C. demersum*, other submerged vegetation, and emergent vegetation at our water access points developed from our drone imagery. As described in detail in Liu et al.[29], we applied a deep learning fully convolutional neural network with classical U-Net architecture. The workflow of our deep learning approach of semantic segmentation on aquatic habitat consisted of: (1) data preprocessing, (2) making label masks (land, open water, submerged vegetation or emergent vegetation; Fig. 4) for the semantic segmentation, (3) training a convolutional neural network model (U-Net architecture using 80% of the data), and (4) validating the model on new satellite imagery (that is, inference using the remaining 20% of the data). To measure how closely the predicted mask was to the manually annotated masks pixel by pixel, we used binary cross-entropy as the loss function to evaluate the model weights of the convolutional neural network. The accuracy metric was defined by the number of pixels labelled correctly divided by the total number of pixels:

$$\text{Pixel accuracy} = (\text{TP} + \text{TN})/(\text{TP} + \text{TN} + \text{FP} + \text{FN})(\%) \tag{1}$$

where TP is true positive, TN is true negative, FP is false positive, and FN is false negative.

### Data analysis

All non-economic statistical analyses were conducted in R-3.4.2 and R-4.1.1 (https://www.r-project.org/). The non-economic data and R code for this study are provided as csv and RMarkdown files, respectively, that accompany this paper on Zenodo (see Data availability and Code availability). The economic analyses were conducted in Stata 16.

**Agricultural land use study.** Even though 16 of the 23 sites used in this study were also part of the vegetation removal study, only baseline data across all sites and non-manipulated control sites were used in our analyses to ensure that these manipulations were not confounded with our agricultural-based analyses (Supplementary Fig. 2). To determine whether village-level agricultural land use predicted the number of infected children, while controlling for other site attributes, we began with a full regression model of all covariates, including: agricultural land use, freshwater habitat cover, water access area, and village population. We also assessed whether crop and freshwater habitat coverage at 0.5-km, 1-km or 2-km radii was the best predictor of human infection. We performed model selection by Akaike information criteria (AIC) using the AICcmodavg package for all possible subsets of the site-level predictors (Supplementary Tables 10–12). We performed the above model selection for two separate binomial models in the MASS package[38] to predict the baseline number of children infected with urogenital schistosomiasis or intestinal schistosomiasis (conducted separately; Supplementary Tables 10–12) at all 23 sites. Between 2016 and 2018, 180 children left the study (88% retention rate), with drop outs occurring as children left the school and/or emigrated to another site.

We examined whether agricultural cover was positively associated with fertilizer use reported in the household survey and whether the use of fertilizer was positively associated with aquatic vegetation cover, using linear regression models. Outliers were tested for using residuals and q-q plots when warranted. We also used linear regression to test whether baseline human prevalence was positively correlated with post-treatment prevalence because our path model combined these data (Extended Data Fig. 4 and Supplementary Table 9), and thus assumed a strong and consistent local infection risk even after drug treatment. The association between schistosomiasis prevalence in children and total crop cover within 0.5 km was tested using a binomial regression, using the number of positive and negative children tested per a site. McFadden's pseudo-$R^2$ was also calculated (Supplementary Tables 13 and 14).

To quantify the relationships among agricultural cover, aquatic habitat, snail hosts, and human infection, we performed path analyses using the piecewiseSEM package[39]. We created an initial global path model incorporating all data from all baseline infection and infection post-treatment rounds that followed snail data collection (Supplementary Fig. 2 and Supplementary Table 15). We included all hypothesized causal pathways between agriculture and human infection that were supported by available literature and our study design (Supplementary Table 1[16]). We could not perform a child-level path model, because piecewisesem() required a single input dataset where each response variable can vary for each observation (row) and thus we aggregated each response variable in the dataset per year at the village level (but see the child-level analyses below for consideration of individual-level effects). All pathways had a random effect of village to account for repeated sampling. All variables that functioned as independent variables in the path analyses were summarized at the village level, standardized using the scale() function, and modelled with a Gaussian error distribution. Before scaling, all count variables were natural log-transformed, as was vegetation mass because it was positively skewed. For infection prevalence, which only functioned as a dependent variable, we used a binomial error distribution. We performed model selection by dropping non-significant predictors from our initial global and compared nested models using AIC until all predictors were significant (Supplementary Tables 16–18). Given that our path analysis used mixed models to account for repeated sampling of sites, we report both marginal and conditional $R^2$ values (Supplementary Table 19), which are based on only fixed effects or both fixed and random effects, respectively. Although the full path model displayed in Fig. 1b has never been tested, many of the individual paths in the model are well-established in the literature (for example, ref. 16 and Supplementary Table 1), providing clear a priori directional hypotheses (that is, support for one-tailed tests) for the paths in our site-level path model.

Given that our path model could only be performed at the hierarchical level of the site, we also performed a separate mixed-effects binomial model at the child level to determine whether predictors identified as important by a previous study[16], such as child gender and age, influenced our findings. The results of this child-level regression generally agreed with our site-level path model, but with reduced statistical power; thus, these results were relegated to Supplement (Supplementary Tables 51–54).

**Aquatic vegetation removal cluster randomized controlled trial.** We estimated average and 95% confidence intervals for the vegetation mass (in g) sampled at the same random points before and after the first removal using the plyr package[40] (Extended Data Fig. 2 and Supplementary Tables 23 and 24). We used the glmmTMB package[41] to evaluate how the log-transformed quantity of vegetation removed (kg) at the water access point level changed over the study using fixed effects for removal round (1–10), water access area (in $m^2$), an interaction between round and area, and the number of labour hours used during removal. We also included a random term for removal round nested within water access point to account for re-sampling.

To determine whether total snail counts in 2017 and 2018 were impacted by vegetation removal, we used the glmmTMB package[40] to compare a Poisson, negative binomial, and a zero-inflated negative binomial model (ZINB; Supplementary Table 25), each with the same fixed effects for vegetation removal treatment (hereafter 'treatment'), manipulation time (a factor for before or after treatment), an interaction term between treatment and time, and a nested random term for sampling visit within point location within water point to account for re-sampling the same points before and after removal (Supplementary Table 26). Model selection using AICc values favoured a ZINB model (Supplementary Table 25), likely because sampling points without snail habitat generally had no snails during the study. To calculate the effects in our ZINB model, we used the effects package[42] and plotted the interaction between time and treatment using ggplots2 package[43] (Fig. 2c). Finally, we performed a Tukey's pairwise post hoc contrast on the ZINB model above using the lsmeans package[44]. We also used a Pearson's correlation to test for the association between the log-transformed quantity of vegetation (in kg) removed and the change in snail counts for time points before and after the removal (Fig. 2b).

To determine if village-level rate of *Schistosoma* infection was negatively associated with the vegetation removal intervention, we performed a generalized linear mixed-effects Poisson model (GLMM) with a log link using the lme4 package. Only children with both urine and faeces samples tested were included in the models. We predicted infection rate for each *Schistosoma* species separately at the child level using fixed predictors for treatment (removal or control), time (before or after), and an interaction term between treatment and time. We also included fixed predictors for child gender, school class, and a factor for whether sites were on the lake or river, and included a random intercept term for time nested within village to properly account for temporal sampling (Supplementary Tables 30, 31 and 37). We also used the same predictors and random terms above to perform negative binomial GLMMs to separately predict child egg burden (natural log-transformed egg counts) for each schistosome species (Supplementary Tables 30, 32, 38). We intentionally applied a Poisson model with a log link to our binomial prevalence data to estimate incident rate ratios because it offers a conservative test of our intervention, leading to greater type II errors (that is, false negatives)[45]. For all models, we selected human infection data per site for the year preceding the start of vegetation removal (2017 for 3 site pairs and 2018 for 5 site pairs) and for one year after vegetation removal to follow methods provided for a BACI analysis with multiple sites[46] The dredge function in the MuMIn package[47] was used to fit all subsets of the primary model and to compute model-averaged regression coefficients, standard errors and cumulative AIC weights as a measure of variable importance (Supplementary Tables 31, 32, 37 and 38). We averaged all models with a delta AIC less than two using the model.avg function in the MuMIn package. Estimated marginal means and standard errors were calculated for both control and removal sites in the before and after time periods and the means before and after were compared (Supplementary Table 29) using the emmeans package[48].

To determine how human behaviour at water access points was influenced by vegetation removal, we used the ordinal package[49] to perform a mixed model using the ordinal response level of water contact immersion as the dependent variable (see Supplementary Table 33), and with the following fixed predictors: intervention time, intervention, the interaction between intervention time and intervention, age group, gender of the individual, and time of day of each observation (Extended Data Tables 3 and 4 and Supplementary Tables 34–36). We included a random term for time nested within site to account for correlation within observation rounds. We then used the same fixed and random terms above but in a Gaussian mixed model to predict the ln-transformed duration of water contact (in minutes) of each observed individual (Extended Data Tables 3 and 4).

**Crop compost experiments.** To determine whether compost improved crop yield, we performed negative binomial regression to separately predict the total number of pepper and onions at the end of our split-plot experiments with fixed effects for compost treatment (C, TC or NC), fertilizer treatment (U or NU), site, and an interaction term between the compost treatment and fertilizer (Supplementary Tables 40 and 41). A mixed effect model was used to account for harvest round for peppers and site was included as a fixed effect. We then used a Gaussian error distribution using the same fixed and random terms above to separately predict natural log-transformed pepper mass, onion mass and onion diseases (onion rot) (Supplementary Tables 40 and 41).

**Livestock feed experiment.** To analyse sheep growth rates among treatments, we performed two linear regression analyses for each sheep age group (juveniles and adults) with the percentage of *C. demersum* in the feed as the continuous independent variables and one with the percentage change in sheep weight and another with final weight as the dependent variables (Fig. 3g,h and Supplementary Table 44). A separate mixed-effects model with sheep ID as the random intercept, sheep mass as the dependent variable, and interactions among age of the ewes (juvenile or adult), date, and percentage of *C. demersum* in the feed was conducted to test for interactions among time and treatments.

**Private economic benefits of using aquatic vegetation as compost.** To determine economic value of compost before accounting for the costs of vegetation removal, transport, and compost application, we first estimated the marginal physical product (MPP) by separately regressing the (natural) log-transformed fruit yield (in kg $ha^{-1}$) of pepper and onion using binary indicator variables for each compost treatment (Supplementary Table 55). We also included a factor for site for pepper because pepper crop trials were performed in two sites. We also generated kernel density plots and stochastic dominance tests of yield by compost treatment for both peppers and onions, to determine variation across the whole yield distribution. We then calculated the expected marginal revenue product of compost by multiplying the MPP estimates from above by the expected price of each crop and then converting the MPP to per metric ton of compost. To determine the marginal cost of the compost, we multiplied the sum of the labour time spent removing vegetation and labour time creating and applying the compost per compost treatment by the estimated average cost of labour for horticultural work in our study region provided by KU Leuven and the Institut Sénégalais de Recherches Agricoles Bureau d'Analyses Macro Economiques (Supplementary Fig. 12). We also added the cost of cart rental to transport the compost to the field to produce the marginal cost per metric ton of surface and tilled compost. For additional details on the economic analyses, see Supplementary Information, appendix 2.

**Private economic benefits of using aquatic vegetation as livestock feed.** To estimate economic costs of *C. demersum* as a livestock supplement, we used the cost per calorie of each food type. We used 159 calories per 100 g, 210 calories per 100 g and 350 calories per 100 g, as the nutritional content of *C. demersum*, peanut straw and cornmeal, respectively[50] (Supplementary Table 45). The cost of 1 kg bag of cornmeal is 290 XOF (US $0.50) and the cost of one kg of peanut straw is

281–375 XOF (US $0.49–US$0.65), whereas it costs less than 5 XOF (US $0.01) to produce 1 kg of *C. demersum* (Supplementary Table 45). Thus, a single calorie of cornmeal costs 8.28 XOF and a single calorie of peanut straw costs 13.39–17.85 XOF and a single calorie of *C. demersum* costs 0.2 XOF (Supplementary Table 45). Given that the sheep are fed *C. demersum* in calorie equivalence to the cornmeal feed or peanut straw, the expectation is that there should not be significant differences in weight gain across the different treatment groups, which is consistent with what we found in our experiment ($P = 0.86$; Fig. 3g,h). For additional details on the economic analyses, see Supplementary Information, appendix 2.

**Public economic benefits of aquatic vegetation removal.** To calculate the public health benefit of the vegetation removal, we began by calculating the disability-adjusted live years (DALYs) averted due to the reduction in *S. mansoni* infection prevalence among school-aged children. Disease burden in DALYs is calculated by summing the years of life lost (YLL) and years lost to disability (YLD) from a disease or condition. Given that the WHO data indicate that schistosomiasis causes very few deaths in Senegal since 2016, and no deaths in the 5–29-year-old age range, we assume that the change in YLL is zero. So, we focus on the reduction in DALYs through a reduction in YLD. The induced change in YLD per person can be calculated by multiplying the estimated reduction in *S. mansoni* infection prevalence (ΔRI) by the estimated disability weight (DW) for schistosomiasis. As the intervention was done at the site level, we then multiply by the average village population (POP) to calculate the DALYs gained for the community. We then use the conservative valuation of each DALY at the gross national income (GNI) per capita for Senegal in US dollars (GNIpc) to calculate the monetary value of the averted DALYs. Finally, we divide the monetary value of the averted DALYs by the total amount of compost ($C$) that would have been produced if all vegetation removed was composted, using high-end and low-end estimates of the vegetation loss in the composting process. This yields the money metric public health (DALY) benefit per metric ton of compost. This estimate follows the equation

$$\text{Public health benefit} = -\frac{(\Delta\text{RI} \times \text{DW} \times \text{POP} \times \text{GNIpc})}{C} \qquad (2)$$

Supplementary Table 52 describes the parameters and their data sources. We estimate the public health benefit per metric ton of compost to be $17.36 on the low end, with a high-end estimate of $22.21; the public health benefit of 1 kg vegetation used in animal feed is 0.01.

The expected public health benefit of $19.79 adds 15–22% to the gross private benefits from composting the harvested aquatic vegetation. Applying this public health gain to the private gains associated with onion and pepper yields results in an inclusive estimated benefit-to-cost ratio of removing vegetation and converting it to compost that now ranges from 3.1 to 8.8. For animal feed, the expected public health benefit adds 1–25% to the gross private benefits. Adding this public health gain to the private gain yields benefit-to-cost ratios of −0.39 to 0.46. For additional details on the economic analyses, see Supplementary Information, appendix 2.

### Reporting summary

Further information on research design is available in the Nature Portfolio Reporting Summary linked to this article.

## Data availability

All the data generated or used for this Article are deposited in Zenodo: https://doi.org/10.5281/zenodo.7765059.

## Code availability

All the code used for this Article are deposited in Zenodo: https://doi.org/10.5281/zenodo.7765059.


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**Author contributions** J.R.R. conceptualized the experiments, directed the project and analyses, and wrote the majority of the manuscript. C.J.E.H. and A.S. contributed to figure development and statistical analyses, and helped to write sections of the manuscript. C.J.E.H., C.D., C.W., S.B. and R.A.N. performed field sampling, data collection and curation of field data. A.J.C. and I.J.J. provided the drone imagery and helped with some of the fieldwork. C.W. acquired the DigitalGlobe grant for the satellite imagery and conducted the remote sensing analyses. A.J.L. conducted the fertilizer use survey that was funded by D.L.-C. C.B.B. and M.J.D. performed economic analyses and contributed to writing those sections of the manuscript and to general editing. N.J., S.S. and G.R. directed the human sampling. A.T.L. collected human infection samples. A.-M.S. curated the human data. N.J. and M.S. oversaw the livestock feed trials. D.J.C. contributed to the original idea development. J.R.R., C.J.E.H., C.W., A.J.C. and I.J.J. collected the data to compare the quadrat and sweep net sampling protocols. J.R.R., G.A.D.L., N.J., J.V.R., G.R. and S.H.S. developed the grant that funded much of this research. G.A.D.L. and S.H.S. contributed to some of the conceptualization and methods development, site selection and baseline analyses. All co-authors contributed to manuscript editing.

**Competing interests** The authors declare no competing interests.

**Additional information**
**Supplementary information** The online version contains supplementary material available at https://doi.org/10.1038/s41586-023-06313-z.

**Correspondence and requests for materials** should be addressed to Jason R. Rohr.


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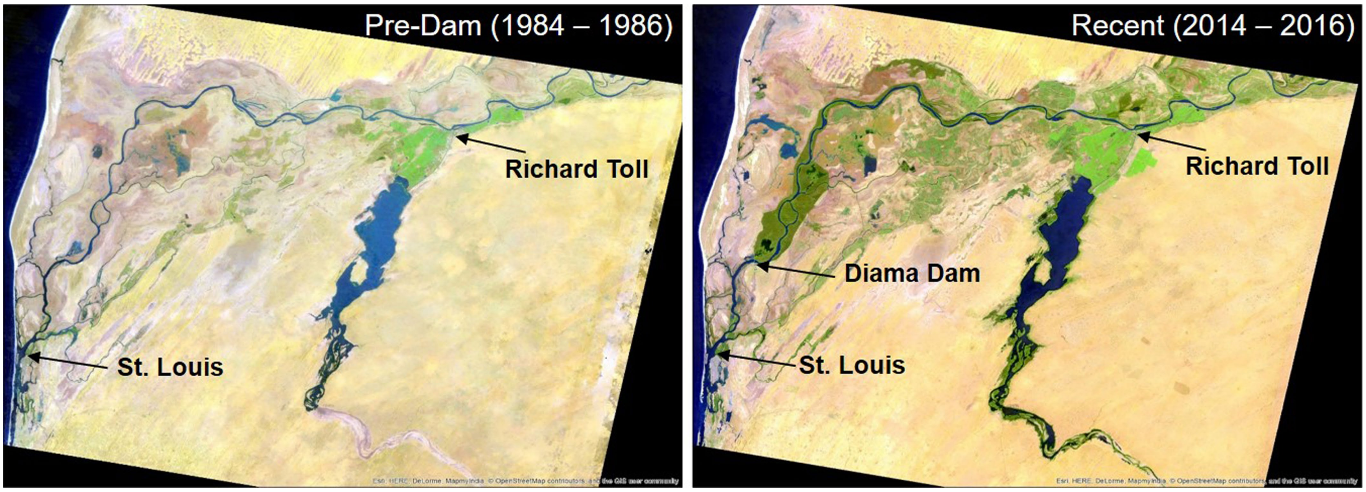
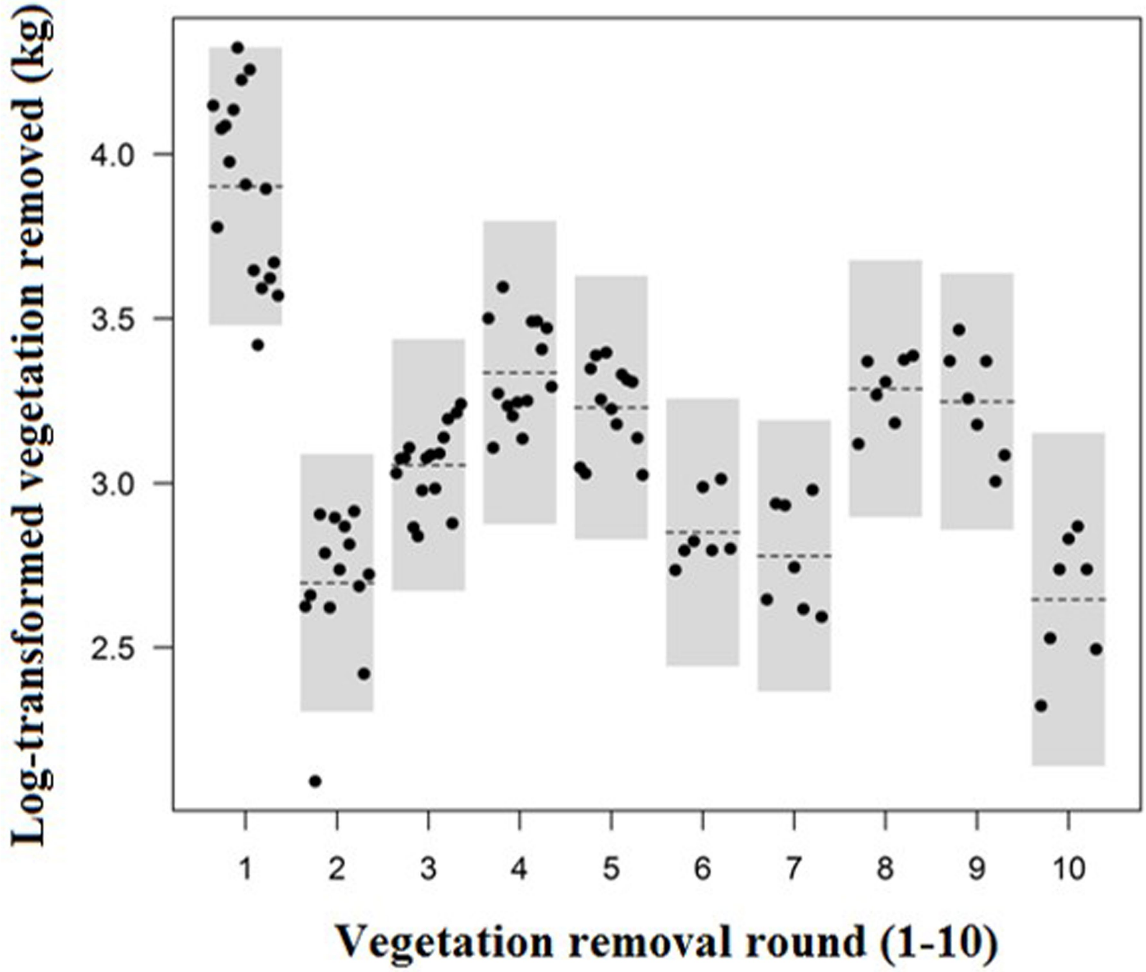
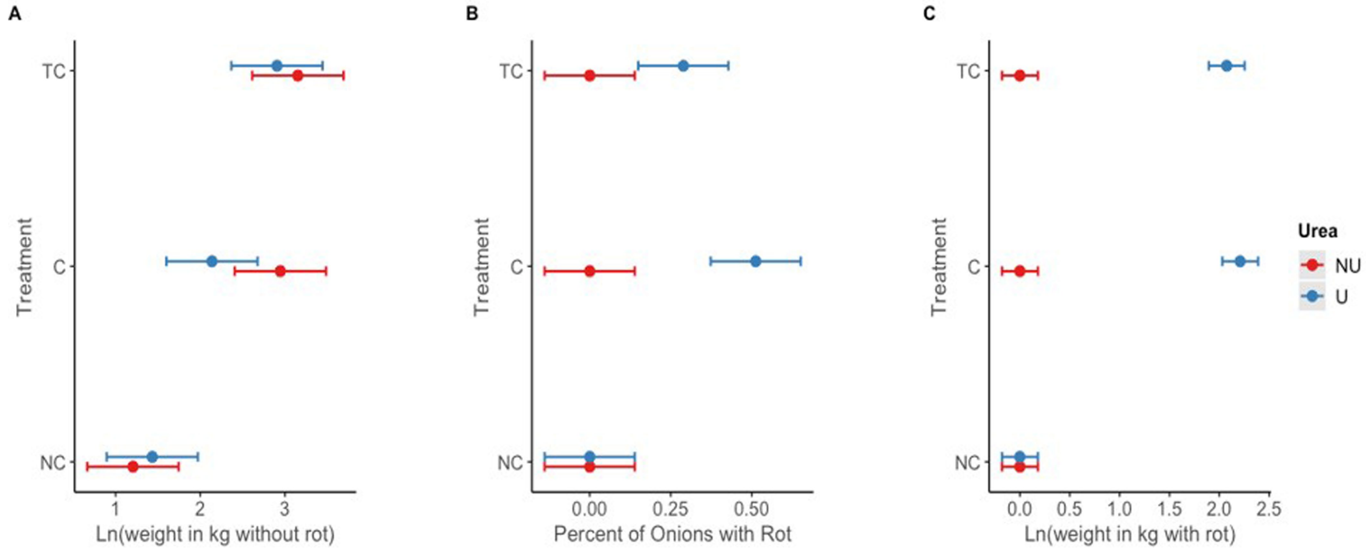


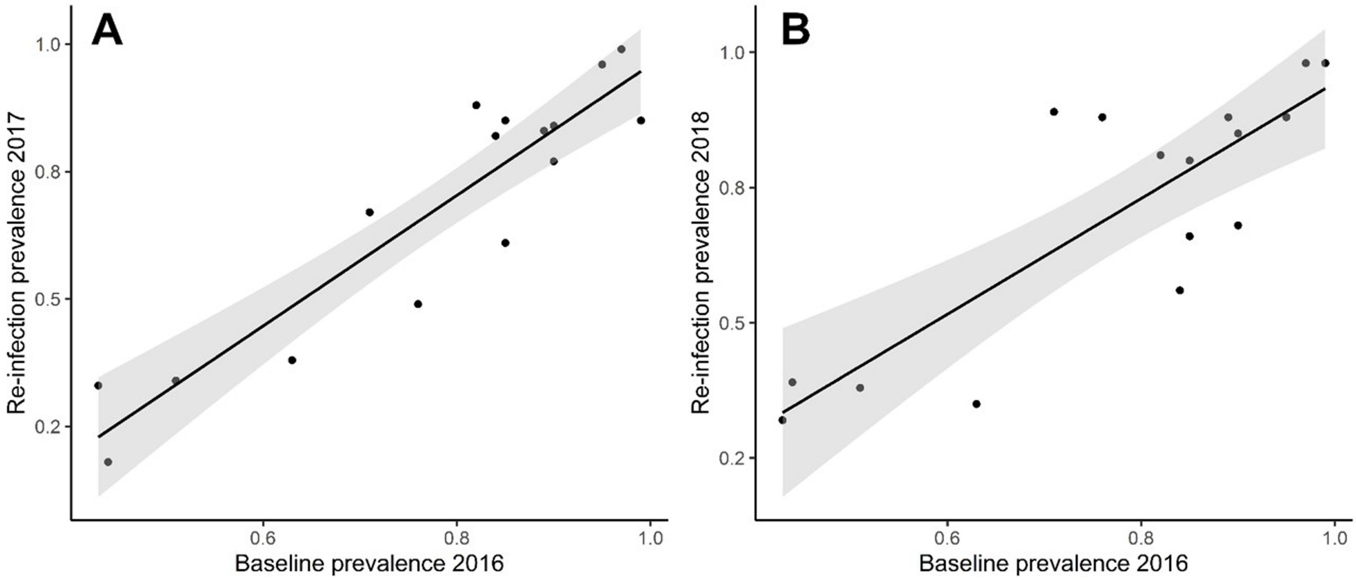

**Extended Data Fig. 1 | Google Earth Engine images of the St. Louis/Richard Toll region of Senegal before (1984–1986) and after (2014–2016) the opening of the Diama Dam.** on August 12, 1986, which was constructed to reduce saltwater intrusion and facilitate irrigation of the region. Note the profound increase in the amount of greenery in the landscape after the opening of the Dam. Image attribution: Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, and the GIS user community.




**Extended Data Fig. 2 | Log-transformed estimated quantity of vegetation removed (kg) for each removal round (1–10) during the study.** Each point represents an independent water access point, the dashed line is the median, and the gray rectangles represent a 95% confidence interval.




**Extended Data Fig. 3 | Amount and effect of onion rot across urea and compost treatments.** Per11m2 subplots, the **(A)** ln-transformed kg of onions unaffected by onion rot, **(B)** proportion of kg of onions with onion rot, and **(C)** ln-transformed kg of onions with onion rot all as a function of crossed compost and urea fertilizer treatments (shown are marginal means and 95% CI; C: compost, TC: tilled compost, NC: no compost, U: urea, NU: no urea; n = six plots for each of the six treatments, three plots at each of two villages).




**Extended Data Fig. 4 | Human baseline prevalence versus infection post-treatment.** Bi-variate scatterplots (with 95% confidence bands) of human baseline prevalence at 16 sites sampled in 2016 versus infection post-treatment in 2017 **(A)** and in 2018 **(B)**.

**Extended Data Table 1 | Evidence that there was no detectable difference in population sizes, sizes of water access points, amount of surrounding agriculture, water, or fertilizer use, or starting amount of aquatic vegetation between control and vegetation removal villages based on a Welch's *T* test**

| | Mean | | SE | | Welch's $T$ | $P$ |
|---|---|---|---|---|---|---|
| Intervention | Control | Removal | Control | Removal | | |
| Village population | 855.50 | 1107.88 | 152.56 | 197.34 | -1.01 | 0.33 |
| Sq. km total crop 0·5km | 0.51 | 0.39 | 0.06 | 0.07 | 1.27 | 0.23 |
| Sq. km water 0·5km | 0.06 | 0.11 | 0.03 | 0.04 | -0.95 | 0.35 |
| Field area (ha) | 75.21 | 114.14 | 18.76 | 18.53 | -1.48 | 0.16 |
| Total fertilizer (ha) | 37.89 | 77.45 | 8.30 | 18.59 | -1.94 | 0.08 |
| Mean non-emergent vegetation area ($m^2$) | 1077.73 | 1097.31 | 423.40 | 252.19 | -0.04 | 0.97 |
| Mean access site area ($m^2$) | 3036.31 | 2659.81 | 857.56 | 487.96 | 0.38 | 0.71 |

**Extended Data Table 2 | Descriptive statistics for total snail counts at the sweep-level for each year, time (before or after vegetation manipulation), and manipulation treatment**

| Year | Time | Treatment | N | Average | Std. dev. | Std. error | Median | Lower 95%CI | Upper 95%CI |
|---|---|---|---|---|---|---|---|---|---|
| 2017 | Before | Control | 74 | 6.59 | 11.01 | 1.28 | 3 | 4.06 | 9.13 |
| 2017 | Before | Removal | 101 | 13.14 | 31.37 | 3.12 | 0 | 6.96 | 19.32 |
| 2017 | After | Control | 73 | 5.21 | 15.82 | 1.85 | 0 | 1.54 | 8.87 |
| 2017 | After | Removal | 119 | 0.28 | 1.21 | 0.11 | 0 | 0.06 | 0.50 |
| 2018 | Before | Control | 240 | 2.25 | 5.99 | 0.39 | 0 | 1.48 | 3.02 |
| 2018 | Before | Removal | 240 | 3.11 | 7.76 | 0.50 | 0 | 2.12 | 4.10 |
| 2018 | After | Control | 225 | 1.89 | 4.11 | 0.27 | 0 | 1.35 | 2.43 |
| 2018 | After | Removal | 225 | 0.94 | 2.76 | 0.18 | 0 | 0.58 | 1.31 |
| 2019 | Before | Control | 225 | 2.92 | 13.12 | 0.87 | 0 | 1.19 | 4.65 |
| 2019 | Before | Removal | 240 | 5.17 | 18.03 | 1.16 | 0 | 2.86 | 7.47 |
| 2019 | After | Control | 239 | 3.46 | 10.87 | 0.70 | 0 | 2.06 | 4.85 |
| 2019 | After | Removal | 240 | 3.99 | 10.67 | 0.69 | 0 | 2.63 | 5.35 |

**Extended Data Table 3 | Count of water contact observations by level of water immersion (ordinal score 1-5), child gender and class (1-3) for each manipulation treatment and time**

| | | | | Level of water immersion (score 1-5) | | | | |
|---|---|---|---|---|---|---|---|---|
| Gender | Time | Class | Treatment | 1 | 2 | 3 | 4 | 5 |
| F | after | 1 | control | 2 | 6 | 7 | 2 | 3 |
| F | after | 1 | removal | 1 | 3 | 5 | 0 | 27 |
| F | after | 2 | control | 0 | 9 | 7 | 0 | 4 |
| F | after | 2 | removal | 0 | 7 | 22 | 0 | 4 |
| F | after | 3 | control | 0 | 9 | 6 | 1 | 1 |
| F | after | 3 | removal | 1 | 9 | 7 | 0 | 11 |
| F | before | 1 | control | 8 | 0 | 9 | 0 | 6 |
| F | before | 1 | removal | 3 | 3 | 6 | 3 | 23 |
| F | before | 2 | control | 7 | 3 | 6 | 0 | 5 |
| F | before | 2 | removal | 3 | 4 | 6 | 1 | 13 |
| F | before | 3 | control | 2 | 2 | 7 | 0 | 2 |
| F | before | 3 | removal | 2 | 5 | 8 | 3 | 6 |
| M | after | 1 | control | 0 | 11 | 2 | 1 | 24 |
| M | after | 1 | removal | 1 | 5 | 0 | 0 | 51 |
| M | after | 2 | control | 0 | 5 | 1 | 0 | 1 |
| M | after | 2 | removal | 0 | 1 | 1 | 0 | 3 |
| M | after | 3 | control | 0 | 6 | 2 | 1 | 0 |
| M | after | 3 | removal | 0 | 3 | 4 | 0 | 1 |
| M | before | 1 | control | 1 | 1 | 4 | 6 | 8 |
| M | before | 1 | removal | 1 | 5 | 6 | 0 | 37 |
| M | before | 2 | control | 2 | 2 | 7 | 0 | 0 |
| M | before | 2 | removal | 0 | 0 | 2 | 0 | 5 |
| M | before | 3 | control | 0 | 1 | 2 | 1 | 2 |
| M | before | 3 | removal | 0 | 3 | 0 | 0 | 4 |

**Extended Data Table 4 | Average duration of water contact (min) by level of water immersion (ordinal score 1-5), child gender and class (1-3) for each manipulation treatment and time**

| | | | | Level of water immersion (scores 1-5) | | | | |
|---|---|---|---|---|---|---|---|---|
| Gender | Time | Class | Treatment | 1 | 2 | 3 | 4 | 5 |
| F | after | 1 | control | 13.0 | 14.5 | 27.6 | 25.0 | 29.0 |
| F | after | 1 | removal | 1.0 | 48.7 | 23.0 | 0.0 | 26.1 |
| F | after | 2 | control | 0.0 | 12.9 | 16.1 | 0.0 | 21.5 |
| F | after | 2 | removal | 0.0 | 27.7 | 19.2 | 0.0 | 27.5 |
| F | after | 3 | control | 0.0 | 12.9 | 17.7 | 20.0 | 46.0 |
| F | after | 3 | removal | 1.0 | 28.0 | 17.3 | 0.0 | 26.1 |
| F | before | 1 | control | 8.1 | 0.0 | 14.0 | 0.0 | 25.2 |
| F | before | 1 | removal | 2.0 | 28.3 | 21.7 | 4.0 | 22.7 |
| F | before | 2 | control | 16.7 | 28.3 | 15.7 | 0.0 | 24.2 |
| F | before | 2 | removal | 3.0 | 21.0 | 27.0 | 1.0 | 24.5 |
| F | before | 3 | control | 5.0 | 22.0 | 17.4 | 0.0 | 35.5 |
| F | before | 3 | removal | 33.0 | 6.6 | 20.1 | 27.0 | 20.8 |
| M | after | 1 | control | 0.0 | 10.6 | 20.0 | 38.0 | 16.6 |
| M | after | 1 | removal | 1.0 | 21.0 | 0.0 | 0.0 | 19.7 |
| M | after | 2 | control | 0.0 | 1.4 | 3.0 | 0.0 | 5.0 |
| M | after | 2 | removal | 0.0 | 6.0 | 22.0 | 0.0 | 32.7 |
| M | after | 3 | control | 0.0 | 6.7 | 6.0 | 23.0 | 0.0 |
| M | after | 3 | removal | 0.0 | 2.0 | 5.3 | 0.0 | 12.0 |
| M | before | 1 | control | 42.0 | 9.0 | 32.5 | 10.2 | 30.1 |
| M | before | 1 | removal | 4.0 | 11.6 | 11.7 | 0.0 | 33.6 |
| M | before | 2 | control | 1.5 | 1.5 | 1.3 | 0.0 | 0.0 |
| M | before | 2 | removal | 0.0 | 0.0 | 3.5 | 0.0 | 6.8 |
| M | before | 3 | control | 0.0 | 5.0 | 7.5 | 4.0 | 7.5 |
| M | before | 3 | removal | 0.0 | 4.7 | 0.0 | 0.0 | 10.8 |

**Extended Data Table 5 | Effects of vegetation removal and time on water quality and water chemistry in the before-after-control-impact experiment**

| Intervention | Time | N | Temperature | Conductivity | Salinity | Dissolved Oxygen ppt | pH | Nitrate | Phytoplankton Ft value | Periphyton Ft value |
|---|---|---|---|---|---|---|---|---|---|---|
| Control | Before | 16 | 29.3 (1.0) | 206.9 (142.9) | 0.10 (0.07) | 4.8 (3.5) | 7.1 (0.5) | 0.55 (0.88) | 351.1 (260.0) | 2476.1 (3790.6) |
| Control | After | 16 | 28.8 (1.9) | 180.1 (110.3) | 0.08 (0.05) | 5.6 (2.2) | 6.8 (0.4) | 0.63 (0.80) | 358.8 (283.7) | 3862.4 (3153.1) |
| Removal | Before | 23 | 29.5 (1.5) | 194.0 (77.5) | 0.09 (0.04) | 3.4 (2.5) | 7.5 (1.1) | 0.26 (0.27) | 260.6 (275.9) | 1869.2 (2381.4) |
| Removal | After | 23 | 27.7 (3.4) | 179.8 (75.7) | 0.13 (0.21) | 2.4 (2.3) | 7.3 (0.5) | 0.42 (0.58) | 372.5 (420.4) | 3085.3 (3289.7) |
| *p*-value for Intervention * time | | | 0.09 | 0.54 | 0.36 | 0.08 | 0.95 | 0.92 | 0.43 | 0.95 |

Shown are mean values across water access sites with standard error in parentheses. Also shown are the p-values for the intervention-by-time interactions from mixed effect models with site included as a random intercept. No p-values are <0.05, indicating that there is little evidence to support the hypothesis that the vegetation removal significantly affected water quality or chemistry.

**Extended Data Table 6 | Lab analyses of compost samples collected from three compost pits dug after the initial removal round**

| Sample ID | 1 | 2 | 3 |
|---|---|---|---|
| Moisture (%) | 11.8 | 19.3 | 12.5 |
| pH | 6.6 | 7.2 | 6.3 |
| Total Kjeldahl N (g/L) | 10.60 | 8.69 | 11.91 |
| Ammonia N (g/L) | 0.07 | 0.02 | 0.06 |
| Elemental P (g/L) | 1.74 | 0.91 | 1.16 |
| Elemental K (g/L) | 13.02 | 8.53 | 4.80 |
| Total Solids (g/L) | 881.88 | 807.13 | 875.30 |
| Total Ash (g/L) | 537.21 | 391.64 | 398.16 |
| Cu (g/kg) | 0.02 | 0.01 | 0.02 |
| Mn (g/kg) | 0.19 | 0.55 | 0.33 |
| Zn (g/kg) | 0.05 | 0.02 | 0.04 |

nature portfolio

Corresponding author(s): Jason Rohr
Last updated by author(s): March 25, 2023

# Reporting Summary

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## Statistics

For all statistical analyses, confirm that the following items are present in the figure legend, table legend, main text, or Methods section.

| n/a | Confirmed | |
|---|---|---|
| ☐ | ☒ | The exact sample size (*n*) for each experimental group/condition, given as a discrete number and unit of measurement |
| ☐ | ☒ | A statement on whether measurements were taken from distinct samples or whether the same sample was measured repeatedly |
| ☐ | ☒ | The statistical test(s) used AND whether they are one- or two-sided<br>*Only common tests should be described solely by name; describe more complex techniques in the Methods section.* |
| ☐ | ☒ | A description of all covariates tested |
| ☐ | ☒ | A description of any assumptions or corrections, such as tests of normality and adjustment for multiple comparisons |
| ☐ | ☒ | A full description of the statistical parameters including central tendency (e.g. means) or other basic estimates (e.g. regression coefficient) AND variation (e.g. standard deviation) or associated estimates of uncertainty (e.g. confidence intervals) |
| ☐ | ☒ | For null hypothesis testing, the test statistic (e.g. *F*, *t*, *r*) with confidence intervals, effect sizes, degrees of freedom and *P* value noted<br>*Give P values as exact values whenever suitable.* |
| ☒ | ☐ | For Bayesian analysis, information on the choice of priors and Markov chain Monte Carlo settings |
| ☐ | ☒ | For hierarchical and complex designs, identification of the appropriate level for tests and full reporting of outcomes |
| ☐ | ☒ | Estimates of effect sizes (e.g. Cohen's *d*, Pearson's *r*), indicating how they were calculated |

*Our web collection on statistics for biologists contains articles on many of the points above.*

## Software and code

Policy information about availability of computer code

| | |
|---|---|
| Data collection | No software or code were used for data collection. |
| Data analysis | All economic analyses were conducted with Stata version 16. All the non-economic analyses were conducted with R (version 3.4.2 and R-4.1.1) and R Studio (version 2021.09.0 Build 351- "Ghost Orchid" Release 077589bc, 2021-09-20 for macOS). The code and the RMarkdown html files are provided. The code and files for the economic analyses are also provided. The packages and versions (in parentheses) used for these analyses are as follows. AICcmodavg (2.3-1), car (3.1-1), ciTools (0.6.1), cowplot (1.1.1), effects (4.2-2), emmeans (1.8.2), fmsb (0.7.4), ggplot2 (3.4.0), ggtext (0.1.2), GLMMadaptive (0.8-5), glmmTMB (1.1.5), gridExtra (2.3), jtools (2.2.1), lattice (0.20-45), lme4 (1.1-31), lsmeans (2.30-0), MASS (7.3-58.1), MuMIn (1.43.17), nlme (3.1-160), olsrr (0.5.3), ordinal (2022.11-16), PerformanceAnalytics (2.0.4), piecewiseSEM (2.0.0), plyr (1.8.8), readxl (1.4.1), rmarkdown (2.18), sjPlot (2.8.12), tidyverse (1.3.2), VGAM (1.1-7), visreg (2.7.0). The custom code has been deposited at Zenodo: DOI: 10.5281/zenodo.7765059. |

For manuscripts utilizing custom algorithms or software that are central to the research but not yet described in published literature, software must be made available to editors and reviewers. We strongly encourage code deposition in a community repository (e.g. GitHub). See the Nature Portfolio guidelines for submitting code & software for further information.

## Data

Policy information about availability of data

All manuscripts must include a data availability statement. This statement should provide the following information, where applicable:

- Accession codes, unique identifiers, or web links for publicly available datasets
- A description of any restrictions on data availability
- For clinical datasets or third party data, please ensure that the statement adheres to our policy

All the data are provided with the manuscript. Data were pulled from other sources for the economic analyses are detailed below.

1) Senegalese monthly price reports from ANSD (The National Agency of Statistics and Demography on Senegal): we downloaded 2 years of monthly price reports and digitized the rice, onion, and pepper prices.
2) Euros to USD exchange rate data from FRED, the Federal Reserve Bank in Saint Louis
3) Male agricultural wage data provided by Prof. Miet Maertens (KU Leuven)
4) Le Project d'Appui aux Politiques Agricoles (PAPA) agricultural wage data provided by the Bureau d'analyses macro-économiques (BAME) of the Institute sénégalais de recherches agricoles (ISRA)
5) Global burden of disease study for disability weight for schistosomiasis
6) World Bank Development indicators for Senegal for GNI per capita

## Human research participants

Policy information about studies involving human research participants and Sex and Gender in Research.

| | |
|---|---|
| Reporting on sex and gender | Sex was included in our analyses and output in the Supplemental Materials is provided |
| Population characteristics | The human schistosomiasis data were collected from school-aged children in 16 villages, 8 on the river and 8 on the lake. At the individual level, age, class in school (as approximate for age), and sex were recorded, as was the village ID and if the village was on the lake or a river. See our Supplemental Materials for additional details. |
| Recruitment | For the study testing for an association between agriculture land use and schistosomiasis, we selected 23 sites from a list of >700 sites as fully described by Wood et al. (see reference section for full citation). Briefly, the study region was geographically limited to the administrative regions immediately touching the Senegal River, Lac de Guiers or connected irrigation canals between the Ocean and the Lac de Guiers, in northern Senegal (Fig. S1). This geographic restriction included the districts (and respective communes) of St. Louis (Fass Ngom, Gandon) Dagana (Bokhol, Dagana, Diama, Mbane, Richard Toll) and Louga (K. Momar Sarr, Nguer Malal, Syer) and reduced the eligible sites to 400. Remaining communities were visited on Google Earth (Google Earth 7.1.2.2041) and sites were selected that were not within protected areas, had access to permanent freshwater without large-scale drainage or vegetation clearing projects that could impact snail or plant distributions, a small human population (<2,215 persons), an active school with 30-130 enrolled children, ≤4 water points accessed by community members that were not on private land, and permission from the community leader for us to sample the water access points. After visits to 133 communities from January 2015 to January 2016, 16 communities met the inclusion criteria and were selected for the vegetation removal cluster randomized controlled trial(Fig. S5-6). We relaxed the community population size criterion to <3,000 people to include seven additional sites for the correlational agricultural land use study (i.e., seven sites were only sampled in 2017, whereas the others 16 were sampled repeatedly from 2016-2018). The primary source of water for the communities was the local (open) water access points, as only two communities had a functional water well, and only one of those had electricity. After village-level recruitment, individual-level recruitment was based on the students attending school in the villages that we studied. Given that we did not randomly select village, there could be bias associated with the selection process implemented in this study.<br><br>A power analysis revealed that 75 subjects should be sufficient to accurately quantify infection rates. Additionally, a power analysis with a medium effect size indicated that 8 treated and 8 control communities in a before-after-control-impact design would be sufficient to detect effects of treatment. Hence, we selected 16 communities and targeted and average enrollment of ~75 schoolchildren where possible. Consequently, a total of 1,479 school-aged children were treated with praziquantel at the 16 communities in April 2016 in the cluster randomized controlled trial and 211 school-aged children were treated at the additional seven sites added for the agricultural land use study in 2017 (Table S7-8, S31-32). |
| Ethics oversight | Subject enrollment, informed consent from the parents or guardians of child participants, human sampling, and drug administration were all conducted by EPLS, approved by the National Committee of Ethics for Health Research from the Republic of Senegal (Comité National d'Ethique de la Recherche en Santé; CNERS, Dakar, Senegal; Protocol #SEN14/33), and conducted in accordance with the Declaration of Helsinki III and with the International Ethical Guidelines for Biomedical Research Involving Human Subjects as set forth by the World Health Organization guidelines for good clinical practice37. Additionally, this study was also approved by the University of South Florida Internal Review Board (Protocol #MS7_Pro00017473) and the University of Notre Dame (18-10-4951), and is registered on ClinicalTrials.gov (NCT03187366 Record R01 TW010286). Consent was sought after randomization. Any infected children found during data collection were offered the anti-schistosome drug praziquantel (40 mg/kg) and all human data were anonymized prior to analysis to protect the identity of participants. A full description of participant demographics and numbers of children tested in each site is presented in Table S7-S8, S31. |

Note that full information on the approval of the study protocol must also be provided in the manuscript.

# Field-specific reporting

Please select the one below that is the best fit for your research. If you are not sure, read the appropriate sections before making your selection.

☒ Life sciences ☐ Behavioural & social sciences ☐ Ecological, evolutionary & environmental sciences

For a reference copy of the document with all sections, see nature.com/documents/nr-reporting-summary-flat.pdf

# Life sciences study design

All studies must disclose on these points even when the disclosure is negative.

**Sample size**

A power analysis revealed that 75 subjects should be sufficient to accurately quantify infection rates. Additionally, a power analysis with a medium effect size indicated that 8 treated and 8 control communities in a before-after-control-impact design would be sufficient to detect effects of treatment. Hence, we selected 16 communities and targeted and average enrollment of ~75 schoolchildren where possible. Consequently, a total of 1,479 school-aged children were treated with praziquantel at the 16 communities in April 2016 in the cluster randomized controlled trial and 211 school-aged children were treated at the additional seven sites added for the agricultural land use study in 2017 (Table S7-8, S31-32).

In June 2018, we performed a two factor split-plot experiment wherein we divided a field into six equal rows or blocks, half of which were assigned the whole-plot (33 m2) treatment of fertilizer addition (U = 8 g urea per plant, NU = no urea), with each row divided equally into three randomly assigned split-plot (11 m2) treatments (C = compost added to soil surface, TC = compost hand tilled into the soil, and NC = no compost) (Fig. S9). This same experiment was then repeated in 2019 for onion production on a novel field using the same planting density and spacing as above. Power analyses were not conducted ahead of time as no human subjects or vertebrate animals were used. Sample sizes were determined based on feasibility and the amount of compost, but sample sizes were sufficient given that the effects were significant.

To determine if aquatic vegetation removed from waterways provides a viable livestock feed supplement, we purchased a total of 30 female sheep in two groups of similar sized ewes and randomly assigned each to one of five treatments: 0, 15%, 30%, 45%, and 60% replacement of their standard feed, cornmeal (adults) or peanut straw (juveniles), with Ceratophylum demersum. Sample sizes were determined based on feasibility of maintaining sheep and budget. Two temporal blocks were conducted, one on adults and another on ewes. Additional temporal blocks were considered, but neither temporal block provided any indication of differences in weight gain between standard feed and isocalorically substituting the standard feed of sheep with C. demersum.

**Data exclusions**

Only children with both and urinary and fecal tests for schistosomiasis were included in the analysis, and this was a pre-determined inclusion criterion. Any child with missing data was also excluded for class, sex or village. Data were not excluded in the crop or livestock trials. An influential outlier was removed in Fig. 1E as described in the RMarkdown file.

**Replication**

The level of replications was always the village for the schistosomiasis studies, the plot in the crop studies, and the sheep in the livestock studies. We believe that all efforts at replication/reproducibility were successful.

**Randomization**

All treatments were assigned randomly to replicates in each of our studies.

**Blinding**

For all the schistosoma egg counts of children, the staff counting eggs were not aware of village treatment assignment. For the compost trials, it was not possible for them to be blind because the compost and tilling were obvious during crop harvesting. For the compost and livestock trials, bias is unlikely to be an issue because mass measurements and counts were the primary dependent variable. It is hard to bias mass and counts given that mass is directly read from the scale and counts are made directly. Additionally, the Senegalese farmers, not scientists, recorded and provided the data and had no reason to bias the results in a particular direction.

# Reporting for specific materials, systems and methods

We require information from authors about some types of materials, experimental systems and methods used in many studies. Here, indicate whether each material, system or method listed is relevant to your study. If you are not sure if a list item applies to your research, read the appropriate section before selecting a response.

## Materials & experimental systems

| n/a | Involved in the study | |
|---|---|---|
| ☒ | ☐ | Antibodies |
| ☒ | ☐ | Eukaryotic cell lines |
| ☒ | ☐ | Palaeontology and archaeology |
| ☐ | ☒ | Animals and other organisms |
| ☐ | ☒ | Clinical data |
| ☒ | ☐ | Dual use research of concern |

## Methods

| n/a | Involved in the study | |
|---|---|---|
| ☒ | ☐ | ChIP-seq |
| ☒ | ☐ | Flow cytometry |
| ☒ | ☐ | MRI-based neuroimaging |

## Animals and other research organisms

Policy information about studies involving animals; ARRIVE guidelines recommended for reporting animal research, and Sex and Gender in Research

| | |
|---|---|
| Laboratory animals | All sheep (Ovis aries) were female and a mix of Touabire and Peul-Peul breeds. The adults were two years old, and the juveniles started at six months old. |
| Wild animals | The study did not involve wild animals. It involved domesticated sheep (Ovis aries), which were bought at market. |
| Reporting on sex | We do report on animal sex in the study. |
| Field-collected samples | No field collected samples were used in the study |
| Ethics oversight | A veterinarian in Senegal monitored the sheep, and Dr. Lexi Sack, also a veterinarian, monitored the sheep as well during the summer months when she was in Senegal. The procedures for the sheep trials were approved through the University of Notre Dame Institutional Animal Care and Use Committee protocol number 7444. |

Note that full information on the approval of the study protocol must also be provided in the manuscript.

## Clinical data

Policy information about clinical studies

All manuscripts should comply with the ICMJE guidelines for publication of clinical research and a completed CONSORT checklist must be included with all submissions.

| | |
|---|---|
| Clinical trial registration | The clinical trial is registered on ClinicalTrials.gov (NCT03187366 Record R01 TW010286). |
| Study protocol | Subject enrollment, informed consent from the parents or guardians of child participants, human sampling, and drug administration were all conducted by EPLS, approved by the National Committee of Ethics for Health Research from the Republic of Senegal (Comité National d'Ethique de la Recherche en Santé; CNERS, Dakar, Senegal; Protocol #SEN14/33), and conducted in accordance with the Declaration of Helsinki III and with the International Ethical Guidelines for Biomedical Research Involving Human Subjects as set forth by the World Health Organization guidelines for good clinical practice37. Additionally, this study was also approved by the University of South Florida Internal Review Board (Protocol #MS7_Pro00017473) and the University of Notre Dame (18-10-4951). |
| Data collection | Data were collected from the St. Louis and Richard Toll regions of Senegal. After visits to 133 communities from January 2015 to January 2016, 16 communities met the inclusion criteria and were selected for the vegetation removal cluster randomized controlled trial (Fig. S5-6). We relaxed the community population size criterion to <3,000 people to include seven additional sites for the correlational agricultural land use study (i.e., seven sites were only sampled in 2017, whereas the others 16 were sampled repeatedly from 2016-2018). Compost crop trials were conducted in local field with local Sengalese farmers in 2018 and 2019. Livestock trials were conducted from 2020-2022 just outside of St Louis. |
| Outcomes | Our primary outcome was a difference in the change in human Schistosoma prevalences between the control and intervention arms. This was measured by quantifying both prevalence and egg burdens of Schistosoma mansoni and S. haematobium in schoolchildren after treatment with praziquantel regardless of whether they were infected. A change in snail abundance was our secondary outcome. In both bases, we used a before-after-control-impact analysis to test for these outcomes. The outcomes in the crop trials were onion and pepper counts and masses in response to compost treatments (no compost, tilled compost, non-tilled compost) crossed by fertilizer treatment (urea present or absent). In the livestock trials, we substituted traditional sheep feed isocalorically with the vegetation removed from the local water access points. The primary outcome was the weight of sheep through time. |